UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY
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ANN ARBOR, MICHIGAN 48105-2498

OFFICE OF
AIR AND RADIATION

January 7, 2002

Dear Manufacturer: CCD-02-01 (LDV/LDT)

SUBJECT: Notice of EPA/Industry Road Force Workshop

EPA will be conducting a workshop to discuss road force confirmation and evaluation procedures and EPA's coastdown auditing plans for the future. The workshop has been scheduled for Wednesday, January 30 from 1:00 to 4:00 PM at the EPA National Vehicle and Fuel Emissions Laboratory office building, 2000 Traverwood Drive, Ann Arbor, Michigan.

This workshop is intended to provide manufacturers an opportunity to comment on a draft EPA procedure for road force confirmation before the Agency finalizes the procedure. The proposed procedure is based on the Agency's road force audit experiences from last year. The procedure is outlined in an enclosure to this letter. The workshop will primarily consist of technical discussions, but some policy issues will also be addressed. Manufacturers' feedback at this workshop will be used to guide EPA in the development of road force confirmation and evaluation procedures used in future Agency audits.

An agenda of the workshop has been provided as an enclosure to this letter. If you have any questions or you would like to schedule time for a formal presentation, please contact Mr. Paul Way at (734) 214-4625.

Sincerely,

Christi Poir for

Gregory A. Green, Director
Certification and Compliance Division
Office of Transportation and Air Quality

Enclosures

EPA/Manufacturer Road Force Workshop Agenda

I. Introduction
   1. EPA plans for developing new guidance
   2. The future of the roadload confirmatory program

II. EPA proposal of evaluation/confirmation method
   1. Brief technical introduction to the energy loss method
   2. Example using 2001 confirmatory program results
   3. Questions

III. Limits and Bias
   1. Test variability
   2. Vehicle variability
   3. Vehicle grouping flexibility
   4. Procedural, single vehicle concerns

IV. Enforcement policy

V. Next steps

DRAFT

Road Force Confirmation/Evaluation Procedure

Introduction

For vehicles tested in the EPA emissions and fuel economy programs, road force data is required to accurately simulate actual vehicle operation on a dynamometer. This data is generally obtained by running prototype vehicles through a series of coastdown tests from which road force may then be analytically determined. It is imperative for emissions and fuel economy testing that the road force data derived from prototype vehicles be representative of the final production fleet.

EPA's roadload confirmatory audit program is designed to ensure that there is no unacceptable offset between reported road force data and road force experienced by actual production vehicles.

Background

Beginning with the 2001 model year, emissions and fuel economy testing on the single-roll electric dynamometer is required by the Supplemental Federal Test Procedure (SFTP) requirements. By the 2004 model year, all testing will be conducted on the single roll dynamometer. The transition from the twin-roll to the single-roll dynamometer requires an improved road force confirmatory procedure.

More accurate than the twin-roll dynamometer, which simulated road force based on a two-term equation matched at a single speed, the single-roll dynamometer uses a three-term equation matched at all speeds. This three-term equation ($F = A + Bv + Cv^2$, where F is the road force, v is the vehicle speed and A, B, C, are coefficients representing the combined driveline, tire and aerodynamic drag) is determined by the SAE coastdown technique SAE J2263 or equivalent procedure. The coastdown technique includes the use of real-time on board anemometry and other advances in coastdown test equipment and data analysis, allowing for the accurate determination of vehicle road force.

Past guidance, issued in Advisory Circular No. 55c, allowed manufacturers to use road force at 50 mph and/or 55 to 45 mph coastdown time as confirmation criteria for comparing road force curves. Either criteria evaluates an entire curve based on either a single point or a small segment of the curve. Figure 1 illustrates how confirmed road force curves and dynamometer settings may significantly differ from actual vehicle road force while still meeting the single point comparison criteria. Although these methods are acceptable for a twin-roll dynamometer set at a single speed, they fail to accurately evaluate road force reproduced on the single-roll dynamometer.

The use of the single-roll dynamometer in conjunction with advanced coastdown techniques has eliminated a significant amount of error in road force determination and reproduction, resulting in better dynamometer simulation of actual vehicle operation. In light of these advances, the procedures set forth in Advisory Circular No. 55c, for evaluating road force and reproducing it on a twin roll dynamometer, are not applicable for emissions and fuel economy testing on a single-roll dynamometer. This has been addressed by the December 21, 1998 (CD-98-16) and April 24, 2000 (CD-00-04) Manufacturer Guidance letters. In both letters, confirmatory evaluation of road force and a pass/fail limit associated with such an evaluation has been left to future consideration.

This report details an improved procedure for road force confirmation and evaluation, suitable for use with the single-roll dynamometer and current coastdown techniques. Test and vehicle variability has been estimated based on the results of the 2001 calendar year roadload confirmatory program. Other factors that should be taken into account for the development of pass/fail criteria will also be discussed.

Proposal of new road force evaluation method

The proposed method of roadload evaluation is based on an "energy loss" model. In order to drive a vehicle at constant speed it is necessary that the road exert a force on the vehicle equal to the sum of all resistive forces acting on the vehicle (aerodynamic drag, tire rolling resistance, etc.). In maintaining this force the vehicle supplies energy to make up for loss induced by resistive forces or roadload. In cases of acceleration or deceleration roadload may be considered to "hinder" or "help" the vehicle, respectively, but in either case there is an energy loss associated with roadload.

For a given driving pattern or schedule, the total roadload energy loss may be easily calculated by considering the rate of energy loss for each speed on the schedule and the total amount of time spent at that speed over the entire schedule. The rate of energy loss due to road load may be expressed as $P_v = F_v\, v$, for a specific speed, v, and a known road force at that speed, F_v. Then, for a given speed, the total amount of energy lost due to roadload is simply $E_v = P_v\, t_v$, where t_v is the total time spent at speed v during a driving schedule. Using the definition above, this may be rewritten as $E_v = F_v\, v\, t_v$. The total amount of energy lost due to roadload over a complete driving schedule is then E_v summed over all speeds in that schedule. This quantity may then be used to evaluate and compare multiple roadload curves over the same driving schedule, assuming the schedule is broken into some set of finite speed intervals.

For a driving schedule that spans a reasonable velocity range, this method of evaluation has the benefit of considering the majority of points in a roadload curve, while still maintaining the simplicity of using a single number for comparison and evaluation. This energy loss comparison method is vastly more representative of an entire roadload curve than is a single force point comparison method, as was used for the twin-roll dynamometer. As such, it is well suited for a dynamometer that is capable of reproducing all points on a roadload curve, such as the single-roll electric dynamometer. This method also has the advantage of evaluating roadload within the context of the driving schedules used for emission and fuel economy testing.

Road force data are used at EPA for fuel economy and emissions testing over the city (FTP) and highway (HFET) driving schedules. Thus, the FTP and HFET schedules will be used by EPA to place this energy loss method of evaluation within the context of relevant vehicle testing. In making comparisons between roadload curves, evaluation over the FTP and HFET cycles will emphasize discrepancies at lower and higher speeds, respectively. Since vehicle variation plays a larger role at lower speeds and since roadload curves are extrapolated from coastdown data when below 10 mph, only speeds of 10 mph and above will be considered for evaluation. A sample calculation comparing two roadload curves over the FTP and HFET cycles has been included as Table 1 and Table 2, respectively.

EPA roadload confirmatory program

The primary purpose of the EPA roadload confirmatory program is to ensure that there is no overall bias in vehicle roadload data submitted for emissions and fuel economy testing when compared to production vehicle roadload data. The secondary purpose of the program is to develop, with manufacturer input, a method for confirmatory evaluation of roadload that reflects the increased accuracy provided by the use of a single-roll dynamometer and advanced coastdown techniques.

To date, a total of six 2001 and 2002 model year vehicles (light-duty vehicles/trucks) have been confirmatory tested in this program. These vehicles were randomly selected from vehicles that had received only routine maintenance and had not previously been tested on a dynamometer. In general the vehicles were broken-in to approximately 4,000 miles and received safety and general maintenance inspections before testing. All tests were performed by the manufacturer using procedures equivalent to SAE J2263.

The data obtained through this program are given in Figure 2 and Table 3. Figure 2 also serves as a comparison of the proposed method to a single point (road force at 50 mph) comparison. While the average result of these tests indicates no overall bias in reported roadload, a larger sample size is required to make a conclusive determination. These six vehicles as well as multiple tests on a single vehicle (data not shown) have allowed for an estimate of inherent test and vehicle variation.

Vehicle and test variation were determined by using the energy loss method to evaluate roadload data produced by several coastdown tests in sister vehicles (vehicle variation) and in the same vehicle, with the same driver, under very similar conditions (test variation). The estimated upper limit on combined vehicle and test variation provides a maximum 4% fractional difference in the total energy loss due to roadload over either the FTP or HFET driving schedules.

Pass/Fail criteria and bias

EPA is not proposing any pass/fail criteria at this time. The Agency may adopt pass/fail criteria when it issues final guidance on this subject. Such criteria will have as its base test variability and vehicle variability, but will also consider vehicle grouping flexibility and the precision of the EPA fuel economy tests.

Of these considerations, the most important are test and vehicle variation and grouping flexibility. It would be inappropriate to set a pass/fail limit below the measurement capabilities of the fuel economy test. However, since a small difference in energy loss (on the order of 1%) alters fuel economy within the measurement capabilities of the fuel economy test, this is not a substantial concern. Grouping flexibility should provide the manufacturer with a reasonable bracket for the grouping of similar vehicles without exceeding the pass/fail limit.

In past guidance (Advisory Circular No. 55c), EPA has allowed manufacturers to retest vehicles which were considered failures in a confirmatory program. This allowed manufacturers a chance to prove that a single vehicle failure fell into the category of test/vehicle variation or that the vehicle was somehow unrepresentative of the production fleet. EPA is now considering two methods that use a cut-point to evaluate individual vehicle results.

The first method is to use the cut-point to establish an area of concern. If a vehicle exceeded the cut-point, the manufacturer would be allowed a reasonable period of time to provide additional data or technical discussion which would mitigate EPA's concern that the original road force coefficients were understating the true road forces of production vehicles. If the manufacturer was incapable of satisfying the Agency concerns, EPA would consider the vehicle failed. Using this method, the cut-point would be a lower number than in the second method.

The second method under consideration is to treat the cut-point as an absolute pass/fail limit. If the limit is exceeded, the vehicle is considered to be failed.

In either case, if a vehicle is considered failed, the manufacturer would be required to revise the original coefficients used to certify the vehicles. Furthermore, all testing conducted using the old values must be replaced by new or adjusted test results prior to the CAFE calculation.

EPA is also planning to evaluate audit data for a systematic production fleet bias that indicates that the manufacturers' road forces were understated in the application for certification. In that case, EPA may require a remedy even if this bias falls beneath an adopted pass/fail limit for an individual vehicle.

Table 1. Roadload energy loss figures for each speed encountered in the FTP driving schedule. These calculations have been made using reported A, B, C, coefficients of 20.25 lbf, 0.7466 lbf/mph, 0.01180 lbf/mph^2 and confirmed coefficients of 25.65 lbf, 0.5608 lbf/mph, and 0.01452 lbf/mph^2, respectively.

Speed Distribution of FTP to 1/10 mph:		**Energy loss over FTP (10mph and greater)**		
Speed (mph)	Time (sec)	Reported (ft*lbf)	Confirmed (ft*lbf)	
0.0-9.9	538	0	0	
10.0	4	1695.2	1919.0	
10.1	1	429.5	485.8	
10.2	1	435.2	491.9	
10.3	3	1323.0	1494.0	
10.4	0	0.0	0.0	
10.5	2	905.2	1020.7	
10.6	2	916.9	1033.1	
10.7	1	464.4	522.8	
10.8	2	940.6	1058.1	
10.9	3	1428.7	1606.1	
11.0	2	964.5	1083.4	
11.1	1	488.3	548.0	
11.2	0	0.0	0.0	
11.3	1	500.4	560.9	
11.4	1	506.5	567.3	
11.5	3	1538.1	1721.4	
11.6	1	518.9	580.3	
11.7	0	0.0	0.0	
11.8	2	1062.7	1186.9	
11.9	2	1075.3	1200.1	
12.0	5	2719.9	3033.4	
12.1	2	1100.7	1226.7	
12.2	0	0.0	0.0	
12.3	1	563.2	626.8	
12.4	0	0.0	0.0	
12.5	7	4033.0	4482.5	
12.6	1	582.7	647.2	
12.7	0	0.0	0.0	
12.8	2	1191.7	1321.9	
12.9	3	1807.5	2003.7	
13.0	3	1827.5	2024.6	
.	.	.	.	
.	.	.	.	
.	.	.	.	
56.7	4	33436.3	34637.0	Percent Difference
TOTAL ENERGY LOSS VIA ROADLOAD		3471338.9	3624080.7	4.40%

<u>Sample calculation at 10.0 mph using reported A,B,C coefficients</u>

$E_v = F_v\, v\, t_v$

$E_{10.0\ mph} = (A + B\ 10.0\ mph + C\ (10.0\ mph)^2)\ (10.0\ mph)\ (4\ sec)$

To convert into units of ft*lbf multiply by 5280/3600 ft*h/(mile*sec)

$E_{10.0\ mph} = (28.896\ lbf)\ (10.0\ mph)\ (4\ sec)\ (5280/3600\ ft*h/(mile*sec))$

$E_{10.0\ mph} = 1695.2\ ft*lbf$

Table 2. Roadload energy loss figures for each speed encountered in the HFET driving schedule. These calculations have been made using reported A, B, C, coefficients of 20.25 lbf, 0.7466 lbf/mph, 0.01180 lbf/mph^2 and confirmed coefficients of 25.65 lbf, 0.5608 lbf/mph, and 0.01452 lbf/mph^2, respectively.

Speed Distribution of HFET to 1/10 mph:		**Energy loss over HFET (10mph and greater)**		
Speed (mph)	Time (sec)	Reported (ft*lbf)	Confirmed (ft*lbf)	
0.0-9.9	15	0	0	
10.0	0	0.0	0.0	
10.1	0	0.0	0.0	
10.2	0	0.0	0.0	
10.3	0	0.0	0.0	
10.4	0	0.0	0.0	
10.5	0	0.0	0.0	
10.6	0	0.0	0.0	
10.7	0	0.0	0.0	
10.8	0	0.0	0.0	
10.9	0	0.0	0.0	
11.0	0	0.0	0.0	
11.1	0	0.0	0.0	
11.2	0	0.0	0.0	
11.3	1	500.4	560.9	
11.4	0	0.0	0.0	
11.5	0	0.0	0.0	
11.6	0	0.0	0.0	
11.7	0	0.0	0.0	
11.8	0	0.0	0.0	
11.9	0	0.0	0.0	
12.0	0	0.0	0.0	
12.1	0	0.0	0.0	
12.2	0	0.0	0.0	
12.3	0	0.0	0.0	
12.4	1	569.6	633.6	
12.5	0	0.0	0.0	
12.6	0	0.0	0.0	
12.7	0	0.0	0.0	
12.8	0	0.0	0.0	
12.9	0	0.0	0.0	
13.0	0	0.0	0.0	
.	.	.	.	
.	.	.	.	
.	.	.	.	
59.9	2	18855.1	19563.1	Percent Difference
TOTAL ENERGY LOSS VIA ROADLOAD		4786308.7	4952927.3	3.48%

<u>Sample calculation at 11.3 mph using reported A,B,C coefficients</u>

$E_v = F_v\, v\, t_v$

$E_{10.0\,mph} = (A + B\ 11.3\ mph + C\ (11.3\ mph)^2)\ (11.3\ mph)\ (1\ sec)$

To convert into units of ft*lbf multiply by 5280/3600 ft*h/(mile*sec)

$E_{10.0\,mph} = (30.193\ lbf)\ (11.3\ mph)\ (1\ sec)\ (5280/3600\ ft{*}h/(mile{*}sec))$

$E_{10.0\,mph} = 500.4\ ft{*}lbf$

Figure 1. Example of a reported road force curve that differs significantly from the confirmed curve, while still meeting the single point (road force at 50 mph) comparison criteria.

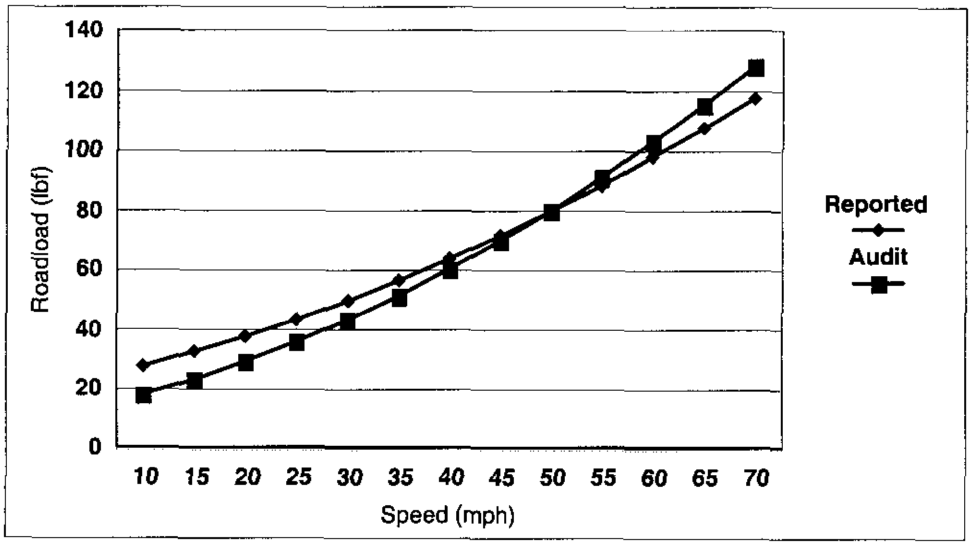

Figure 2. Results of the 2001 calendar year EPA roadload confirmatory program.

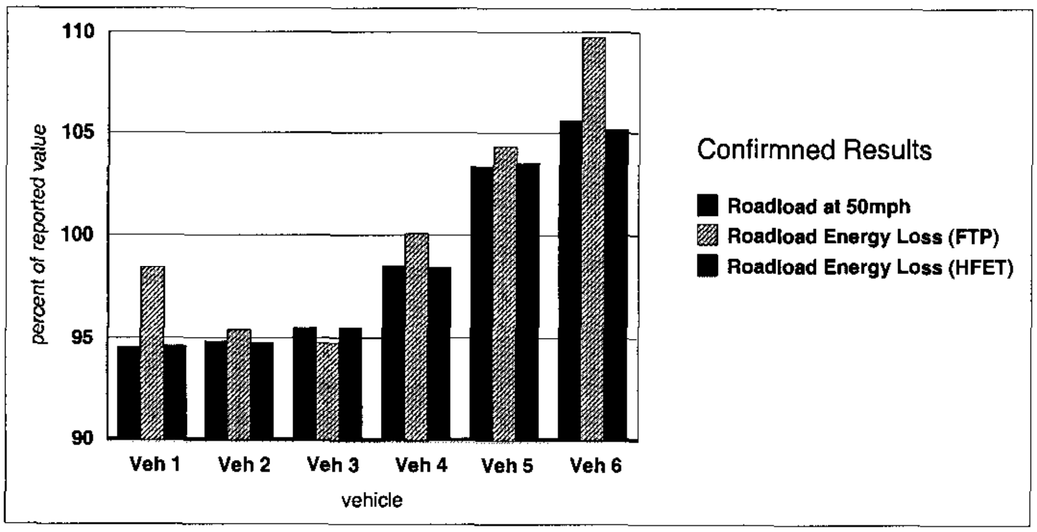

Table 3. Results of the 2001 calendar year EPA roadload confirmatory program, corresponding to data as presented in Figure 1.

Number	Model Year	Reported road force coefficients A	B	C	Confirmed road force coefficients A	B	C
1	2002	40.47	0.7653	0.02914	55.34	0.1887	0.03139
2	2002	19.74	1.1486	0.03055	19.47	1.1237	0.02796
3	2002	19.15	0.4179	0.01682	15.7	0.5036	0.01502
4	2001	38.08	0.2939	0.02767	39.48	0.3473	0.02531
5	2001	20.25	0.7466	0.0118	25.65	0.5608	0.01452
6	2002	37.88	0.2148	0.0415	43.6	0.5486	0.03595